REMARKS

Claims 1-17 are pending in the present application. Claims 1 and 4 have been amended.

Information Disclosure Statements

An Information Disclosure Statement has been filed concurrently along with this Amendment. **The Examiner is respectfully requested to acknowledge receipt of the Information Disclosure Statement, and to confirm that the documents submitted therewith have been considered and will be cited of record in the present application.**

Claim Rejections-35 U.S.C. 103

Claims 1-17 have been rejected under 35 U.S.C. 103 as being unpatentable over the Okamoto reference (U.S. Patent No. 5,298,093) in view of SU 1148893 (abstract), the Corwin reference (U.S. Patent No. 4,735,771) or WO01/57280. This rejection is respectfully traversed for the following reasons.

The present invention relates to a high-grade duplex stainless steel with suppressed formation of intermetallic phases and having excellent corrosion resistance, embrittlement resistance, castability and hot workability.

Based on the fact that, even if corrosion resistance and mechanical properties are remarkably improved in a thin laboratory size of mother alloy manufactured by

optimal design, special conditions should be satisfied to increase the production yield of thick cast products and hot working products in mass production, and to improve corrosion resistance and mechanical properties thereof. Applicants have thoroughly researched the mechanisms of intermetallic phases such as sigma (σ) and khi (χ) showing detrimental effects on corrosion resistance, embrittlement resistance, castability and hot workability.

That is, Applicants have discovered that when alloying elements (atoms) such as Ba, MM (Ce, La, Nd, Pr etc.) and/or Y which have a much larger atomic diameter than basic alloying elements such as Fe, Cr, Mo, Ni, W, Mn and Si, among which Cr, Mo, Si and W facilitate formation of intermetallic phases such as sigma (σ) and khi (χ) were added, the alloying element having a much larger atomic diameter **fill** atomic vacancies operating as a diffusion path for Cr, Mo, Si and W, which are composing elements of sigma and khi phases. Particularly, these alloying elements having a much larger atomic diameter **fill** atomic vacancies in austenitic and ferritic phase-boundaries and crystal grains of ferritic phase, to lower precipitation speed of intermetallic phases so that the alloying elements (atoms) having a larger atomic diameter block diffusion of Cr, Mo, Si W having relatively small atomic diameter, as well as to lower a formation speed of intermetallic phases at a temperature ranging from 1000 to 650°C.

In addition, Applicants have discovered that, because the alloying elements having a large atomic diameter have much lower free energy for thermodynamically forming oxides or oxy-sulfides than Fe, Cr, Mo, W, Ni, Mn and Si, and thus could form

minute and uniform oxides and oxy-sulfides having a diameter below 5 μm, those minute rare-earth metallic mixtures or Ba oxides could additionally block diffusion of Cr, Mo, Si and W at a temperature ranging from 1000 to 650°C, to lower a precipitation speed of intermetallic phases (see page 9, line 27 to page 10, line 14 of the present application).

As acknowledged by the Examiner, the Okamoto reference does not disclose the use of Ba, and also does not the range of Ba, as featured in claim 1.

Moreover, the advantageous effect of adding Ba is described on page 15, lines 4-17 of the present application, wherein Ba having a much larger atomic diameter than the other alloying elements (Fe, Cr, Mo, W, Ni, Mn, Si etc.) of duplex stainless steel is operated as a barrier blocking diffusion of Cr, Mo, Si and W, which are main constituents of brittle intermediate phases such as sigma (σ) and khi (χ) and thus Ba is effective to reduce the diffusion speed, the precipitation speed and the precipitation amount of intermetallic phases. Ba is coupled with oxygen to form oxides, thereby lowering the precipitation speed of sigma and khi phases.

The Okamoto reference discloses that DP3W (UNS S39274) which is high-grade duplex stainless steel containing 3%Mo+2%W, could delay a precipitation speed of sigma phase more than commercial high-grade duplex stainless steels containing 3.8%Mo, such as SAF 2507, UR 52N+ and ZERON 100, **by adding W** in aging heat-treatment for 10 minutes at 850°C. However, the Okamoto reference does not disclose the case where a large-sized ingot and slab are hot-rolled, or a large-sized product is

molten and cast. In such case, corrosion resistance and mechanical properties are deteriorated due to precipitation of sigma (σ) and khi (χ) phases showing high brittleness. However, such problems have been solved in the present application by adding alloying elements such as Ba, MM(Ce, La, Nd, Pr etc.) and/or Y having a much larger atomic diameter than basic alloying elements such as Fe, Cr, Mo, Ni, W, Mn and Si.

Furthermore, the Okamoto reference discloses the following in column 7 regarding duplex stainless steel:

"Second Optional Element Group (Ca, Mg, B, REM)

<u>Calcium (Ca), magnesium (Mg), boron (B), and rare earth metals (REM) all serve to improve the hot workability of the steel by fixing sulfur or oxygen</u>. The duplex stainless steel of the present Invention has good hot workability in itself due to a low S content and the nature of W, which does not serve to accelerate the formation of σ- and similar phase although added in a large amount.

However, when the steel is worked to fabricate it into products with a high reduction in area through forging, rolling, extrusion, or a simlar working process, it is desired that the steel have further improved hot workability. In such cases, one or more elements selected from the second group may be added, as required" (our emphasis added).

As may be seen from the above noted disclosure of the Okamoto reference, one of ordinary skill would not have been motivated to improve the hot workability by more fixing of S, because the Okamoto reference discloses that the alloy has good hot workability in itself due to a low S content and optional elements implementing more fixing of S in case of severe working.

In contrast, the present application is directed into increasing the production yield of thick cast products and hot working products in mass production, which is not considered in the Okamoto reference. Applicants emphasize that even small improvements in yield or other industrial characteristics *per se* are very relevant improvements in large-scale production.

In the present case, Applicants discovered that intermetallic phases composed of Cr, Mo, Si and W are important factors and satisfactory production yield was not obtained only by adding of W <u>which does not serve to accelerate the formation of σ- and similar phases although added in a large amount as in the Okamoto reference</u>.

In order to solve this problem, the present application is mainly directed whereby added Ba blocks diffusion of Cr, Mo, Si and W facilitating formation of intermetallic phases so as to lower precipitation and/or formation speed of the intermetallic phases composed of Cr, Mo, Si and W. These aspects implement obtaining a dense solidified structure for increasing the production yield of thick cast products (see Example 4 of the present application for example).

Regarding the secondarily relied upon Su 1148893 abstract, Applicants direct

attention to the enclosed excerpt of Encyclopedia of Materials Science and Engineering. As disclosed, machinability is broadly understood as the ease with which a metal is cut. Therefore machinability has nothing to do with intermetallic phases such as sigma (σ) and khi (χ) phases in which the present application is mainly involved. Any metal can be made more machinable by dispersing free-machining additions into its structure. Lead (Pb) can be used as a free-machining addition in both brass and low carbon steels. Steel can also be resulfurized (S is added), in which case manganese sulfide (MnS) is the usual inclusion. Free-machining stainless steels can be made using includions such as Tellurium (Te) and Selenium (Se). Ba inclusions may show similar effects in SU 1148893A (abstract).

The free-machining additions have several functions. At the chip-tool interface, Pb or MnS (and Te, Se, Ba) are deformed to very high shear strains. This mechanism is equivalent to internal lubrication within the chip.

Applicants respectfully submit that machinability has nothing to do with the formation of intermetallic phases such as sigma (σ) and khi (χ) phases. Applicants therefore respectfully submit that one of ordinary skill would have no motivation to modify the Okamoto in view of the SU 1148893 abstract to solve the intermetallic phase problems in the production yield of thick cast products and hot working products.

Regarding the secondarily relied upon Corwin reference, Applicants direct attention to the enclosed excerpt of Corrosion Engineering by Mars G. Fontana. As disclosed, oxidation by gaseous oxygen is an electrochemical process (the reaction

involves generation and consumption of electrons). It is not simply the chemical combination of metal and oxygen on a molecular scale, $M + \frac{1}{2} O_2$, but consists of two partial, spatially separated processes:

$M \rightarrow M^2 + 2e^-$ (oxidation at metal-scale interface)

$\frac{1}{2} O_2 + 2e^- \rightarrow O_2$ (reduction at scale-gas interface),

with new MO lattice sites produced either at the metal-scale interface or at the scale-gas interface.

Therefore, only metal ions are able to affect the oxidation behavior. This behavior is apparent in Figure 11-1 of the excerpt from Corrosion Engineering. Figure 11-1 shows that the oxide layer serves simultaneously as 1) an ionic conductor, 2) an electronic conductor, 3) an electrode at which oxygen is reduced, and 4) a diffusion barrier through which electrons pass and ions must migrate over defect lattice sites (V_m and V_o).

In the Corwin reference, those elements appearing for the most part in Groups IA (Li, Na, K), IIA (Be, Mg, Ca, Sr, Ba) and IIIB (Y, La, Ce) of the Periodic Table are added in small quantities. These elements, as ions, enter into the protective oxide scale, greatly reducing the amount of oxidation observed due to elevated temperature exposure. That is, these elements show much broader range of atomic diameter. Also, the Corwin reference does not provide any disclosure or suggestion about the formation

of intermetallic phases inside the alloy matrix.

In contrast, in the present application, Ba and MM are added as elements (atoms) and exist as in an atomic state, not as ions. Inside the alloy matrix, these elements intervene with the combining action of Cr, Mo, Si and W, and thereby suppress the formation of intermetallic sigma (σ) and khi (χ) phases. The intervention cannot occur at alloy-scale or scale-gas interface.

Accordingly, Applicants respectfully submit that one of ordinary skill would have no motivation to modify the Okamoto reference in view of Corwin reference, to solve the intermetallic phase problems in the production yield of thick cast products and hot working products.

The WO 01/57280 reference is not directed to duplex stainless steel, but more particularly to grain refining alloy for steel. 'Grain Refining' means reducing sizes of grain of the steel matrix. The material is FeXY. X may be Cr, Mn, Si, Ni and Mo, and Y may be Ce, La, Nd, Pr, Ti, Al, Zr, Ca, Ba, Sr, Mg, C and N. Therefore, the basic compositions are quite different from the present application. This material is added to liquid steel in the tapping ladle in order to control the solidification structure as a small auxiliary agent (page 16, line 14: 3.5 Kg.1 ton: about 0.35%). The resulting solidification structure of the steel shows an extremely fine grain size with the chill zone, i.e., from 0.05 to 0.1 mm, from which the coarser columnar grains grew into the interior for the ingot. Therefore, the resulting dendrite arm spacing was approximately a factor of three smaller than observed in the ingot treated with conventional misch metal

addition. Therefore, the WO 01/57280 reference relates only to decreasing grain sizes of the steel considerably more than the conventional method, and has nothing to do with suppression of intermetallic phases such as sigma (σ) and khi (χ) phases.

Accordingly, Applicants respectfully submit that one of ordinary skill would have no motivation to modify the Okamoto reference in view of WO 01/57280, to solve the intermetallic phase problems in the production yield of thick cast products and hot working products. Applicants therefore respectfully submit that the high-grade duplex stainless steel of claim 1 would not have been obvious in view of the prior art as relied upon by the Examiner taken singularly or together, and that this rejection of claims 1-3 and 5-17 is improper for at least these reasons.

Regarding claim 4, the Okamoto reference discloses a possible addition of REM as set forth in column 7, lines 37-51. In the Okamoto reference, REM is only one of several optional elements serving to improve the hot workability of the steel by fixing sulfur or oxygen, and that content of REM (mainly La and/or Ce) is at most 0.2% in total when added (see page 6, line 44 of the Okamoto reference). That is, La and/or Ce as pure metals are mainly added to be at most 0.2% in total.

However, in the present application rare-earth metallic mixtures MM, wherein MM is rare-earth metallic mixtures consisting of atoms with atomic numbers from 57 to 71, containing at least 50% or more of Ce, a certain amount of La, Nd, and Pr, minute amounts of Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu and Sc, and 1% or less Fe are added. That is, rare-earth metallic mixtures of mainly Ce-La-Nd-Pr-Fe are added.

Applicants respectfully submits that the subject matter of claim 4 defining MM with such a composition defines over the Okamoto reference.

Incidentally, such MM is an alternative to adding Ba, by which the same problem, being to reduce the precipitation speed of brittle, intermediate phases by fixing S, is solved. Thus, it is neither known from nor rendered obvious by the Okamoto reference to add such MM. Furthermore, pure metal La and Ce of the Okamoto reference are very expensive, wherein the rare-earth metallic mixture MM is relatively cheap. Accordingly, Applicants respectfully submit that the high-grade duplex stainless steel of claim 4 would not have been obvious in view of the prior art as relied upon by the Examiner taken singularly or together, and that this rejection of claims 4-7 is improper for at least these reasons.

Conclusion

The Examiner is respectfully requested to reconsider and withdraw the corresponding rejection, and to pass the claims of the present application to issue, for at least the above reasons.

In the event that there are any outstanding matters remaining in the present application, please contact Andrew J. Telesz, Jr. (Reg. No. 33,581) at (571) 283-0720 in the Washington, D.C. area, to discuss these matters.

Pursuant to the provisions of 37 C.F.R. 1.17 and 1.136(a), the Applicants hereby petition for an extension of three (3) months to July 17, 2007, for the period in which to

file a response to the outstanding Office Action. The required fee of $1020.00 should be charged to Deposit Account No. 50-0238.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment for any additional fees that may be required, or credit any overpayment, to Deposit Account No. 50-0238.

Respectfully submitted,

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Enclosures: Excerpt of Encyclopedia of Material Science and Engineering
Excerpt of Corrosion Engineering